

## MULTIFOCAL OPHTHALMIC LENS

This application is a continuation in part of application Ser. No. 465,477 filed on Jan. 16, 1990 now U.S. Pat. No. 5,166,712 which is a division of application Ser. No. 366,319 filed Jun. 14, 1989 now U.S. Pat. No. 4,898,461, which is a continuation of Ser. No. 56,050 filed Jun. 1, 1987, now abandoned.

### BACKGROUND OF THE INVENTION

This invention relates to a multifocal ophthalmic lens and in particular to a lens adapted for implantation in an eye, such as an intraocular lens (IOL), or to be disposed on or in the cornea, such as a contact lens, corneal onlay or corneal inlay. The corneal inlay may also be regarded as an implant.

A specific embodiment shown in my U.S. Pat. No. 4,898,461 (which patent is incorporated by reference herein) discloses a multifocal ophthalmic lens which includes a central zone circumscribed by multiple concentric, annular zones. The central zone may have a vision correction power for intermediate correction and from there the vision correction power varies progressively in a radial outward direction to a far vision correction power, and then to a near vision correction power. In the specific embodiment of this patent, the progressive vision correction power is varied between far and near through the several zones.

A multifocal ophthalmic lens of this type provides multiple images on the retina. One or more of these images is in focus and one or more of these images is out of focus. The human brain selects the in-focus image to enable a multifocal ophthalmic lens of this type to function well at near, intermediate and far viewing distances.

### SUMMARY OF THE INVENTION

For given lighting conditions, there is only a fixed amount of light that will pass through a lens to the retina. This invention utilizes a multifocal lens to distribute the light most effectively among near, intermediate and far images.

In terms of viewing distances, far is often regarded as the most important because good far vision is required for certain tasks, such as driving, where safety is important. Also, when viewing an object at a far viewing distance, lighting conditions and distance to the object often cannot be altered. Near vision is very important for reading and other close work. However, near vision is often needed under circumstances where light intensity can be increased and viewing distance altered, if needed. Finally, intermediate images are generally least important.

A multifocal lens can be designed to have an increased depth of focus, but this reduces image quality. Conversely, image quality can be increased at the expense of depth of focus. A feature of this invention is to increase depth of focus in certain portions of the lens and to provide maximum image quality in other portions of the lens and to locate the high depth of focus and high image quality portions of the lens in a way to enhance vision for far, near and intermediate objects.

One aspect of this invention is to provide improved image quality and light intensity for near images. This can be accomplished by maintaining the near vision correction power of appropriate zones of the lens substantially constant for a major segment of the near vi-

sion correction power region of each zone and by providing a central zone having an increased depth of focus.

For near vision, the working distance, i.e., the distance between the eye and the object, can usually be varied with relative ease as when a person reading adjusts the distance between his eyes and the material being read. For this reason, it is desirable to concentrate as much light as possible at a single near location to provide maximum image quality at such near location. This is accomplished by the major segments of each near vision correction power region which have substantially constant near vision correction power. Although this inherently reduces the depth of focus at such major segments, this is typically immaterial at this near location because of the ability to easily adjust the working distance. Although this feature is useful in contact lenses, corneal onlays and corneal inlays, it is particularly applicable to an intraocular lens (IOL) because, in that instance, the patient has minimal residual accommodation, i.e., the ability of a normal eye to see objects at different distances.

As explained more fully below, it is desirable to space the near vision correction power regions radially outwardly from the central zone of the lens. This can be accomplished by providing the multifocal ophthalmic lens with a plurality of annular zones circumscribing an optical axis with each of first and second of the annular zones having a far vision correction power and a region with a near vision correction power. The vision correction power between the far and near vision correction powers is progressive. Each of the regions has a major segment in which the near vision correction power is substantially constant. This provides improved image quality and light intensity for near images and less intensity for intermediate images where image quality is of less importance.

This invention is generally applicable to a multifocal ophthalmic lens of the type which is adapted to be implanted in an eye, such as an IOL or disposed on or in the cornea, such as a contact lens, a corneal onlay or a corneal inlay. A multifocal lens of this type has a reduced depth of focus as compared with a monofocal lens. This reduction in depth of focus is particularly noticeable for a multifocal intraocular lens because, as indicated above, the patient has only minimal residual accommodation. Another feature of this invention is to increase the depth of focus of the central zone of the multifocal ophthalmic lens. This invention employs several concepts, which can be used separately or in combination to increase the depth of focus of the central zone of the lens.

First, the depth of focus is related to the aperture or pupil size, and a smaller pupil provides a larger depth of focus. For example, for a 2 millimeter diameter pupil, there is a depth of focus of about 2 diopters or more. In bright light, the pupil of the human eye is typically approximately 2 millimeters in diameter. To take advantage of this inherent depth of focus obtainable by a relatively small aperture, the central zone of an IOL constructed in accordance with this invention is preferably, but not necessarily, about 2 to 2.1 millimeters in diameter. Because of the effective optical zone size at the location of a contact lens, the central zone of a contact lens constructed in accordance with this invention is preferably, but not necessarily, about 2.25 mm in diameter. In addition, this invention preferably includes additional features which increase the depth of focus of